Photoelectric effect

You shine light on a metal and electrons jump off. If you increase the intensity of the light, more electrons jump off but with about the same kinetic energy.
If you increase the frequency of the light, the electrons jump with more kinetic energy but less of them if the intensity is the same.
If you decrease the frequency, at some point the electrons stop jumping, regardless of the intensity.

What's the deal?

Planck and Einstein - light consists of particles, called photons (Newton called them corpuscles), that have both wave and particle properties. (wave-particle duality)

E=hf is the energy of the photon
Intensity, I=power/area = (hf x number of photons)/(time x area)

so if you keep the intensity the same and

increase the frequency, the number of photons must be less to have the same energy

IB data booklet

$E_{max} = hf - \phi$

h is Planck's constant = 6.63×10^{-34} Js

f is frequency, in Hz = s^{-1}

E_{max} = maximum kinetic energy of the kicked off electrons, in J.

ϕ= work function - energy required to kick an electron off, in J.

eg. You shine radiation on Sodium and observe electrons to jump off when the wavelength is at most 520nm. You then shine light of 420nm on the sodium, with intensity of 1.0 mW/m^2.

a) what is the work function of Sodium?

set Emax = 0 at the maximum wavelength

$E_{max} = hf - \phi$

$0=hf-\phi$

$\phi=hf = hc/\lambda =$

$6.63\times10^{-34}Js\times3.00\times10^{8}m/s/5.20\times10^{-7}m$

6.63x3/5.2=3.825

$\boxed{3.8 \times10^{-19}J}$

3.825/1.602$\boxed{=2.4 \text{ eV}}$

$1eV=1.602x10^{-19}J$
(because $1e = 1.602x10^{-19}C$)

b) what is the maximum kinetic energy of the kicked off electrons when you shine 420nm on the sodium?

$E_{max} = hf - \phi = hc/\lambda - \phi$
$E_{max} = 6.63x10^{-34}Jsx(3.00x10^8 m/s)/4.2x10^{-7}m - 3.8\ x10^{-19}J =$
6.63x3/4.2=4.7357 4.7357-3.8=0.9357
$\boxed{9.4x10^{-20}J}$ or 9.4/1.6=5.875 or $\boxed{0.59eV}$

c) how many photons are hitting the sodium/per unit area per second?

$I = 1.0mW/m^2 = hc/\lambda$ x # photons /Area
$1.0x10^{-3}\ J/sm^2 = 4.7357x10^{-19}J$ x # photons /Area
photons /Area= 1/4.7357=0.2112
$\boxed{2.1\ x\ 10^{15}}$ photons per second per m^2

p1048 Problems 15, 19, 25, 27, 29

Heisenberg's uncertainty principle:

Imagine you are in a dark room and you want to know what's around out and you can't move. You could roll stuff and listen to what it hits. But

if you roll a bowling ball, what you hit will move. This isn't a perfect analogy because the stuff in the room has wave properties as well but it's a start.

If you use a higher frequency wave to observe particles, you give the particles more energy and alter their momentum. If you use lower frequency waves, the wavelength is longer and you can't see small things.

Heisenberg quantified this as

$\Delta x \Delta p \geq h/4\pi$ (Hecht text is is over 2π depends on a 2 d vs 3d derivation, I think)

or

$\Delta E \Delta t \geq h/4\pi$

Δx is the uncertainty in the position of the particle

Δp is the uncertainty in the momentum of the particle

ΔE is the uncertainty in the energy of the particle (virtual particles created out of the vacuum)

Δt is the uncertainty in the time of the energy variation (lifetime of the virtual particle)

Schrödinger equation: particles have wave properties, described by the wave function Ψ, where Ψ^2 is the probability distribution.

Feynman has a classic 50 minute lecture from 1953 describing weirdness of quantum theory: https://www.youtube.com/watch?v=2mIk3wBJDgE

p1079-1080 Problems 37, 39, 45